Monsoonal climate variability and its impact on the susceptibility of rainfall to cause erosion

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1. Abstract

Recent evidence suggests that our climate is changing and is very likely to continue changing in the future, and monsoons are no exception. Monsoonal climate is primarily evident in tropical countries like India where more than 75% of annual rainfall is caused by monsoons. All erosive rain is concentrated during the monsoon months. As a result, any change in monsoon rainfall intensity or quantity will bring changes in its erosivity patterns. This paper studies Indian monsoonal rainfall variabilities in the past 50 years. Since rainfall intensity is the prime determinant of soil erosion, emphasis is placed on the change in rainfall intensity in the recent past decades. The more intense the rainfall is the more it is to be susceptible to cause erosion. This susceptibility when quantitatively estimated is termed the rainfall erosivity factor in the Revised Universal Soil Loss Equation2 model (RUSLE2). This paper presents the results of a study that was carried out on how the change in monsoon rainfall intensity affects the rainfall erosivity factor. It was found that the rainfall erosivities are not only dependent on the quantity but also on the intensity of the rainfall; and most importantly that any change in monsoonal climates will bring substantial change in erosivities.

2. Introduction

Climate change is a well known and has been a much debated issue in recent times and possibly one of the most critical global challenges. Our climate has been changing notably over the past century and those changes are expected to continue in future. Evidences of changes are prominent in the environment through increase in global and regional temperature and strong change in the hydrologic cycles in many parts of the world and including India (Goswami et al, 2006). The amount and intensity of rainstorms has become greater in many places implying more water induced erosion. Such changes are noticed to be very prominent in the tropical countries like India where any change in monsoon hydrological cycle will largely affect soil erosion since the magnitude, frequency and extent of soil erosion is changed by change in rainfall amount and intensity. Increased amount or intensity of precipitation due to climate change will amplify current soil erosion problems in India (Pal and Al-Tabbaa, 2007). It is therefore very important to study the monsoonal climatic variability and its impact on soil erosion in order to develop a predictive capability of soil erosion problems and to improve the soil management.

Rainfall susceptibility to cause erosion, termed rainfall erosivity in the Revised Universal Soil Loss Equation 2 (RUSLE2) (Renard et al, 1997) could be estimated to assess how the rainfall amount and its intensity affects soil erosion for the soil erosion is directly proportional to the rainfall erosivity while other factors are kept unchanged (Wischmeier and Smith, 1978). This study includes an assessment of 50-years daily rainfall data collected from India to identify the changes in precipitation patterns in the past 50 years and their possible effects on rainfall erosivity by studying its variation with change in precipitation amount and intensity in the 50 years. A new method has been used to estimate the erosivity which includes disaggregation of daily rainfall data; and validated on the Australian monsoon data as discussed in detail in Pal (2007). The following sections summarise the procedure of calculating rainfall erosivity and the outcome of this study.

3. Methodology to compute rainfall erosivity

The main concept behind quantifying rainfall erosivity is the computation of the kinetic energy of an erosive rainstorm (Stocking and Elwell, 1976). However, it is not always possible and convenient to measure the kinetic energy of every storm because it varies from storm to storm. But, rainfall intensity is a parameter which can easily be measured. Several works have been carried out to date to find correlations between the kinetic energy and the hourly rainstorms intensity based on experiments at various geographical locations and assumptions. Extensive regression analyses of basic soil-loss data for more than 30 years showed that when factors other than rainfall are held constant, storm soil losses are directly proportional to the product value of two rainstorm characteristics: total kinetic energy of the storm and its maximum 30-minutes rainfall intensity (in 'mm/hr'); as designated by EI_{30} (Wischmeier and Smith, 1958). Among all the numerical models available in the literature, that proposed by Brown and Foster (1987) is the one recommended in RUSLE2. This is because they have an appropriate functional form at lower intensities and is based more on detailed dataset than that used previously. Hence the expression derived by Brown and Foster (1987) is mainly used in the study reported here and the corresponding equation is:

$$e = 0.29\,[1 - 0.72 \exp(-0.05\, I)] \tag{1}$$

where: e = kinetic energy in MJ/ha-mm of rainfall and I = rainfall intensity in mm/hr.

According to this expression, the kinetic energy increases with increase in rainfall intensity and vice versa. Therefore, any change in rainfall intensity will very likely affect the erosivity of rainfall. The total storm kinetic energy (E) in MJ/ha is calculated using the relationship:

$$E = e.\,\Delta V \tag{2}$$

where: ΔV = total storm rainfall (mm).

In order to calculate 'R' (MJ-mm/ha-hr), the annual rainfall erosivity, the storm kinetic energies (E) in a day are multiplied by the corresponding maximum 30-minutes rainfall intensity and are summed for a year. The expression for 'R' is as follows:

$$R = \left[\sum_{t=1}^{T} \left(\sum_{i=1}^{d} (E)_i (I_{30})_i \right)_t \right] \tag{3}$$

where: I_{30} = maximum 30-minutes rainfall intensity expressed in in mm/hr; i = index of the number of storms in each wet day; d = total number of storms in a day; t = index of number of rain days in a year and T = total number of rain days in a year.

4. Results and discussions

Rainfall data were collected from the Indian Meteorological Department, Pune. The rainfall is the maximum along the west coast of India and in north-east India. Among all the regions in India, an area in Kerala (11.5N, 75.5E), extreme south western state of the Indian peninsula, was chosen for this research. Figure 1 shows the 50-year daily rainfall data series for Kerala. Daily maximum precipitation with magnitudes varying from 100 mm to 160 mm usually has a return period between 1-10 years but the same with magnitudes more than 300 mm occurred only once in 1991 as seen in Figure 1. However, more than 200 mm peak has been observed returning several times since the 90's decade. Therefore, there is high possibility of such highly intense rainfall or more to continue to occur in near future (Pal and Al-Tabbaa, 2007).

The rainfall erosivities were estimated using Equations 1 to 3 considering assumptions and methodology as discussed, in detail, in Pal (2007), to study sensitivity of rainfall erosivity to change in monsoon rainfall amount and intensity. Mean monthly variation of the erosivities is shown in Figure 2 (based on 50-year average) and the interannual monsoon erosivity variations are shown in Figure 3. The highest erosivity values are observed during either of the first 2 monsoon months (June/July), usually coinciding with the highest rainfall values as in Figure 2. Therefore, the most critical period is June-July during which approximately 70% of the mean annual erosivity occurs.

The data in Figure 3 that also includes yearly monsoon rainfall indicates that, the higher the monsoon rainfall amount, the higher the corresponding erosivity. However, this is not true for all the years. One major exception is the year 1991, in which the monsoon rainfall erosivity increased dramatically from the previous year (5.4 times), wherein increase in the amount of the rainfall from the previous year was only 4.3%. The erosivity value again dropped as much as 42% from 1991 to 1992 whereas the difference in total rainfall amount in both the years was very negligible. This is because; the rainfall erosivity is a function of both the quantity of rainfall and its intensity. Since 1991 experienced the most intense rainfall in the 50-year record in the study area, the erosivity was such high. 24-hour maximum precipitation in 1990 and 1992 were almost the same (112.3 and 111.8 mm); however, for the lesser amount of total monsoon rainfall occurrence in 1990 than in 1992 (1968 mm and 2727.6 mm) contributed towards a low erosivity value in 1990. There have also been the instances of an increase in erosivity values from the previous year when the annual rainfall quantity decreased. This applies to the years 1993 and 1996 when monsoon rainfalls were 7.6% and 9.4% lower than the previous years; however, the annual erosivity values are 14% and 15% higher respectively. The reason for this is again the variation in rainfall intensities, since, as noticed in Figure 1, all of these years' maximum daily intensity is more than the previous year's (1.15 and 1.95 times respectively).

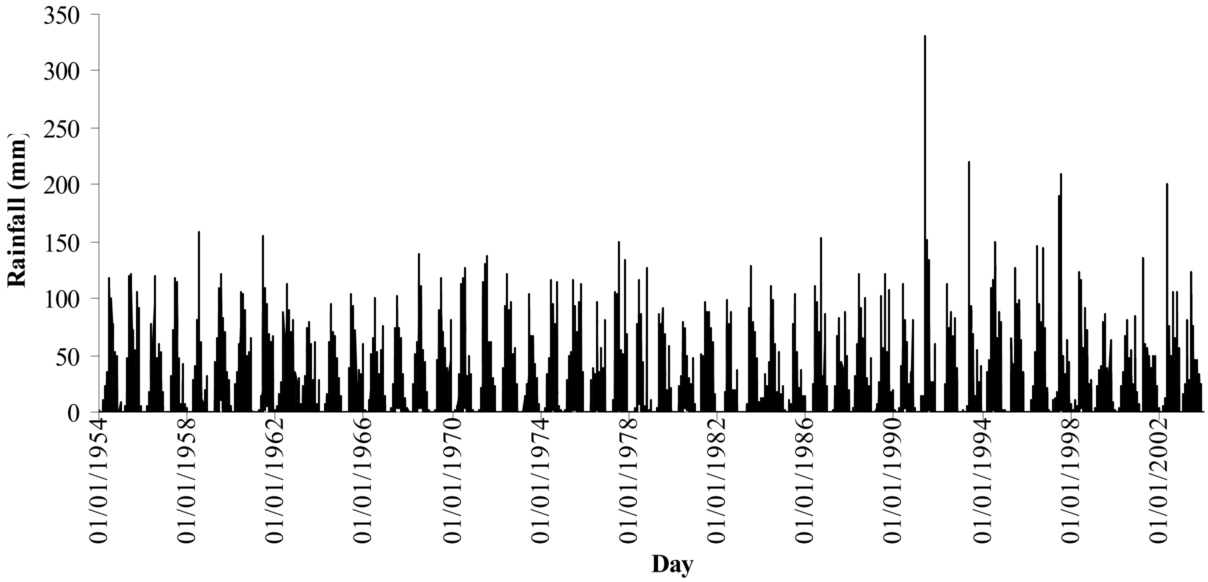

Figure 1 The 50-years daily time series of rainfall in Kerala, India

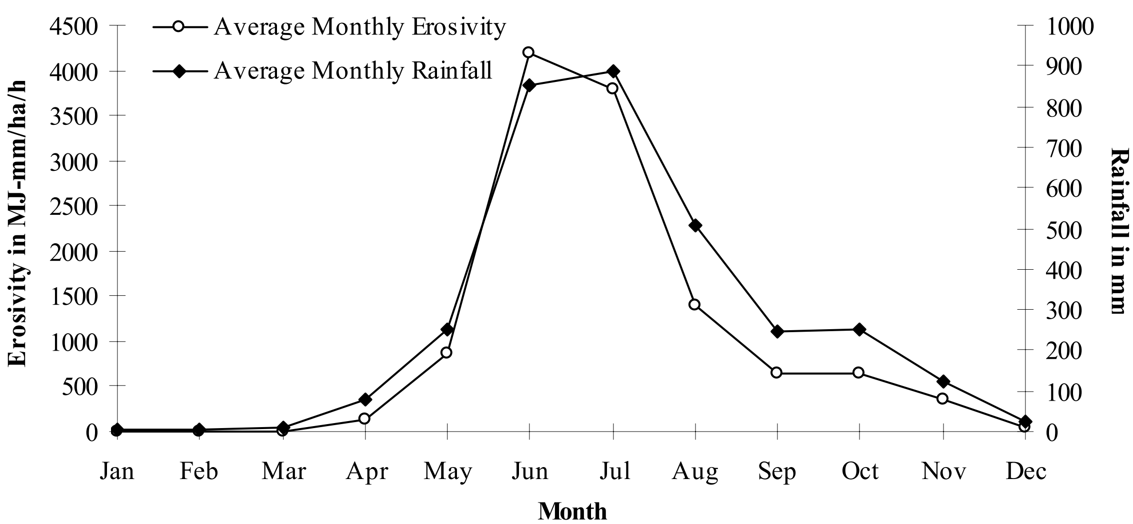

Figure 2 Mean monthly erosivity values for Kerala

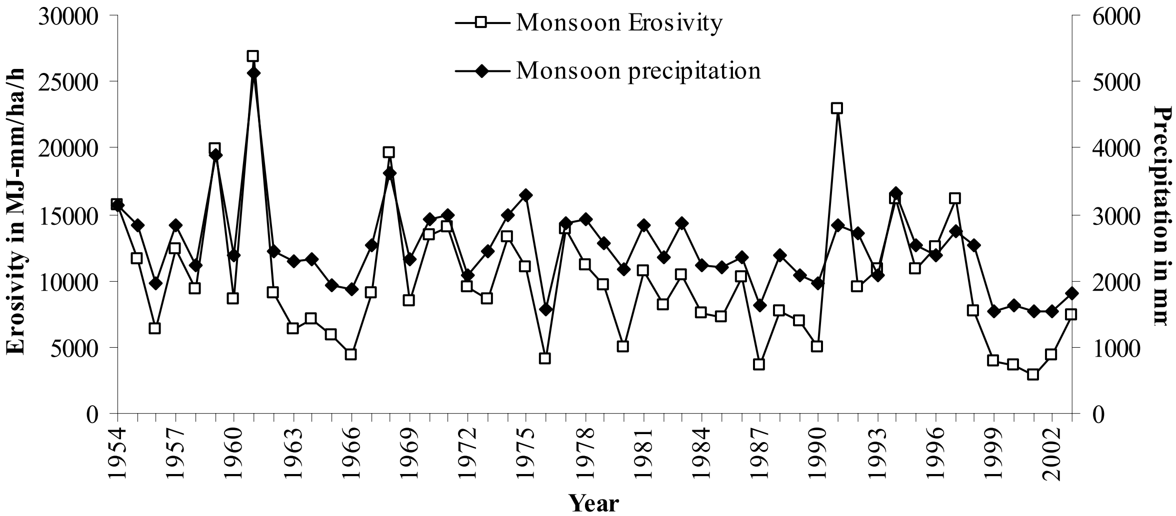

Figure 3 Inter year variation of monsoon rainfall erosivity and rainfall

5. Conclusion

The study observed that, 24-hour maximum precipitation of 100-160 mm usually has a return period ranging from 1-10 years in the study area; however, much more intense rainfall (greater than 200 mm/day) has been observed returning several times since 90's decade. Therefore, an implication of an increase in highly intense rainfall occurrence could also be expected in near future too implying a very high susceptibility of rainfall to cause erosion for rainfall intensity is an important and foremost decisive factor to erosion along with the rainfall amount. The highest erosivity in a year (70%) could be observed during the first 2 monsoon months (June-July) that experience highest rainfall in terms of total amount and the intensity in a year and therefore, is the most critical erosive period. Rainfall erosivity increases with increase in monsoon rainfall quantity; however the variation of the same doesn't always follow the same variation path as monsoon rainfall amount in all the years; the only reason again being the variation in rainfall intensity.

6. References

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